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UPPER CAMBRIAN/LOWER ORDOVICIAN CONODONT AND GRAPTOLITE RECORDS IN THE LARI SECTION, SALAR DEL RINCÓN, PUNA OF SALTA, ARGENTINA

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LARI Creek, also named El Médano Creek, nearby the Salar del Rincón, is located in westernmost Salta Province, northwestern Argentina. It belongs to the Puna geological province, in the southern part of the Central Andean Basin (Moya *et al.*, 1993). In this area, a succession of continental and marine Paleozoic rocks crop out. The lower sequence that bears significant index fossils is intruded by Ordovician volcanic rocks, and covered by clastic and pyroclastic deposits of Cenozoic age (Koukharsky, 1988; Moya *et al.*, 1993; Koukharsky *et al.*, 1996; Galli *et al.*, 2010). This stratigraphic interval is particularly interesting because the index fossils reveal the transitional levels between the Cambrian and Ordovician systems and, therefore, the discussed position of the inter-systemic boundary in South America (Albanesi *et al.*, 2010).

An invertebrate fauna composed of trilobites, sponges, graptolites, and microfossils (conodonts and palynomorphs) was recorded in the Las Vicuñas Formation of the upper Furongian/lower Tremadocian (Moya *et al.*, 1993; Carrera, 1998; Rao *et al.*, 2000; Vaccari *et al.*, 2010; Toro *et al.*, 2011).

The conodonts and graptolites recorded in the upper part of the Las Vicuñas Formation, suggest a probable late Furongian age for the basal levels, and an early Tremadocian age for the uppermost levels, although the assignment of a definite age is still tentative.

GEOLOGIC SETTING AND STRATIGRAPHY

An extensive Paleozoic succession covered by Cenozoic deposits is exposed in the Lari creek (Upper Cambrian-Permian) (Fig. 1). The oldest unit referred to as Tremadocian is the Las Vicuñas Formation (Moya *et al.*, 1993), which is characterized by clastic and pyroclastic rocks, calcarenites and coquinas corresponding to platform environments (Moya *et al.*, 1993; Koukharsky *et al.*, 1996). The basal part of the formation is covered by Quaternary debris, and the upper succession is intruded by Ordovician quartzitic porphyries unconformably covered by the Salar del Rincón Formation (Aceñolaza *et al.*, 1972a y b), which preserves Hirnantian to Llandovery marine faunas (Isaacson *et al.*, 1976; Benedetto and Sánchez, 1990; Vaccari *et al.*, 2010; Galli *et al.*, 2010).

The Cerro Oscuro Formation (Aceñolaza *et al.*, 1972a, b) unconformably overlies the Salar del Rincón Formation. Its age is assigned to the Late Carboniferous according to paleobotanical remains. Lower Permian rocks corresponding to the Arizaro Formation (Aceñolaza *et al.*, 1972 a, b) paraconformably overlie the Cerro Oscuro Formation. The youngest units of the area are described as tuffs and ignimbrites of the Tajamar Formation (Neogene), as well as Quaternary clastic deposits and volcanic rocks (Galli *et al.*, 2010, and references therein).

In Lari Creek, the Las Vicuñas Formation is ca. 220 m thick (Moya *et al.*, 1993). The lower 5 m are composed of green-gray silty shales overlain by a succession of pyroclastic rocks and

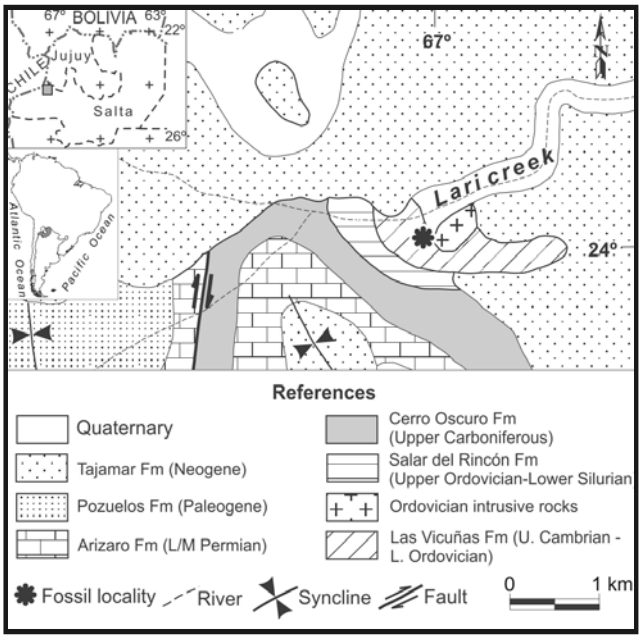

Figure 1. Location map of the study area and geology of Lari Creek, Salar del Rincón (modified from Galli et al., 2010).

quartz sandstones, ca. 132 m thick. The unconformably overlain upper part of the formation is made up of black shales that are partly silicified, and fine sandstones, calcarenites, calcareous shales and coquinas. This upper part of the unit that bears the conodonts and graptolites studied herein, reaches ca. 124 m thick in the measured profile (Fig. 2). These shales are intruded by a quartzitic porphyry in the uppermost strata of the Las Vicuñas Formation.

Coquinas, calcarenites and calcareous concretions are distributed throughout the upper part of the formation; nevertheless, only the two lower beds yielded conodonts. Rao *et al.* (2000) documented *Cordylodus caboti* Bagnoli, Barnes and Stevens, *C. intermedius* Furnish, and *Phakelodus tenuis* (Müller) for the same strata. Additionally, our conodont collection includes *Cordylodus lindstromi* Druce and Jones, *C. proavus* Müller, *C. deflexus* Bagnoli, Barnes and Stevens and *Teridontus nakamurai* (Nogami) (Fig. 3).

The uppermost strata of the Las Vicuñas Formation bear an abundant and monotonous graptolite fauna composed of *Rhabdinopora flabelliformis* cf. *f. parabola* (Bulman) (Fig. 3). The first mention of this fauna was made by Rao *et al.* (2000), who reported the presence of *Rhabdinopora* sp. Recently, Vacarri *et al.* (2010) and Toro *et al.* (2011) cited R. f. *parabola*

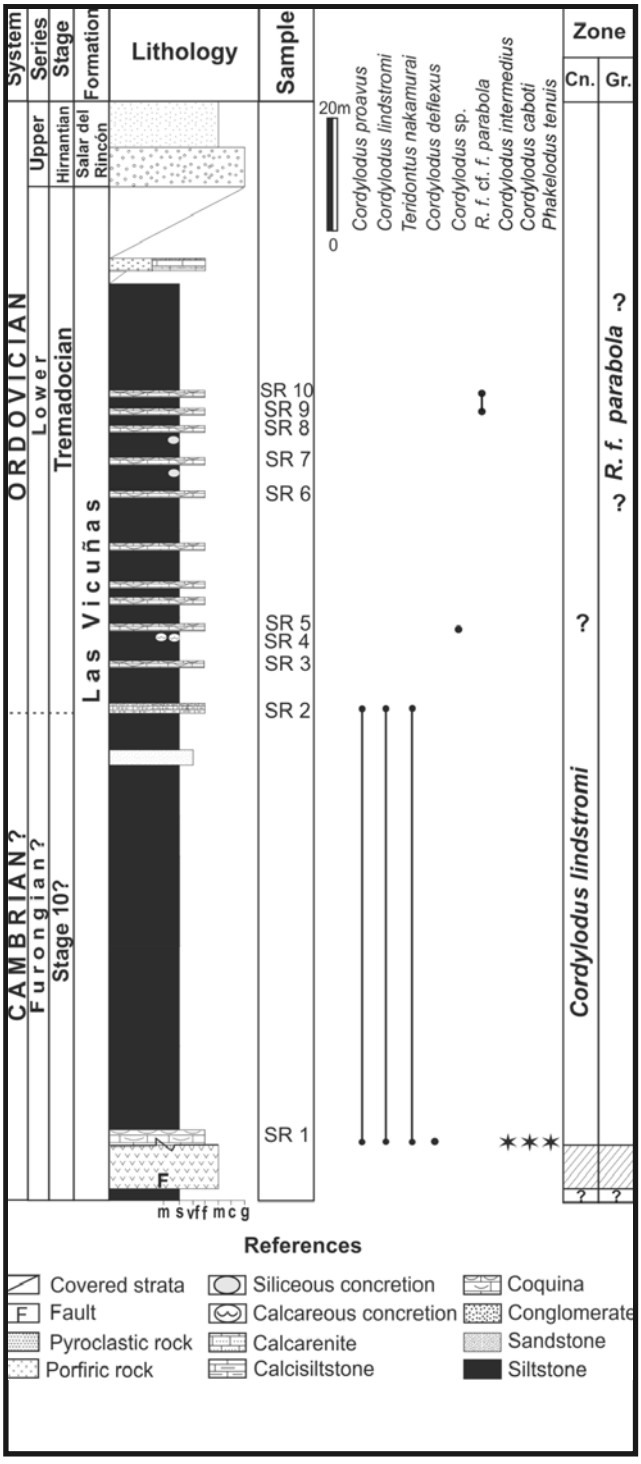

Figure 2. Stratigraphic column of the Las Vicuñas Formation at Lari Creek, with the ranges of the conodonts and graptolites and the corresponding biozonation (Cn.: conodont zone; Gr.: graptolite zone; *R. f. parabola: Rhabdinopora flabelliformis parabola*. Black stars represent the species records by Rao *et al.*, (2000).

few meters above the trilobite *Jujuyaspis keideli* Kobayashi, in the same succession. Other records of trilobites (*Kainella* sp., *Asaphellus* aff. *comunis* Robison and Pantoja-Alor, *Onichopyge* sp.) in this formation are mentioned in Moya *et al.* (1993). Carrera (1998) described the hexactinellid sponge *Larispongia magdalenae* n. sp., recorded in the upper Las Vicuñas Formation.

The Tremadocian succession of Lari Creek was folded and faulted during the Ocloyic Phase, as evidenced by the angular unconformity between the Las Vicuñas Formation and the Hirnantian/Llandovery strata of the Salar del Rincón Formation (Donato and Vergani, 1985; Moya *et al.*, 1993). Other tectonic events were dated as Carboniferous and Cenozoic, related to Andean tectonics (Moya *et al.*, 1993). The studied section corresponds to a faulted syncline with minor folds in the hinge.

BIOSTRATIGRAPHY

Conodonts

All of the conodont species recorded in the studied section span the Cambrian/Ordovician boundary; although, the conodont association documented is characteristic of the *Cordylodus lindstromi* Zone. It is scarcely represented in coquinas and calcarenites of the basal upper part of the Las Vicuñas Formation, in the samples SR1 and SR2 (Fig. 2). The conodont record includes *Cordylodus lindstromi* Druce and Jones, *C. proavus* Müller, *C.deflexus* Bagnoli, Barnes and Stevens, and *Teridontus nakamurai* (Nogami) (Fig. 3).

The *Cordylodus lindstromi* Zone was defined in western North America by Miller (1988), and Barnes (1988) recognized it in western Newfoundland. The records of *C. lindstromi* in Utah, Texas and Oklahoma correspond to the *C. lindstromi* and *Iapetognathus* zones according to Nicoll *et al.* (1999). This biozone is represented worldwide with records in Australia, Canada, China, Iran, and Kazajstan (Cooper *et al.*, 2001). In northwestern Argentina, the *Cordylodus lindstromi* Zone was determined in the Cajas range, Tilcara range, and the Parcha area from Cordillera Oriental and the Salar del Rincón from the Puna of Salta province (Rao, 1999; Tortello *et al.*, 1999; Pacheco, 2009; Zeballo *et al.*, 2011, among others), and in the Volcancito Formation, Famatina System (Albanesi *et al.*, 1999, 2005).

The base of the *C. lindstromi* Zone was informally considered as the base of the Ordovician System (Barnes, 1988). Later, Cooper *et al.* (2001) recognized the conodont *Iapetognathus fluctivagus* Nicoll *et al.* as marker of the Cambrian/Ordovician boundary, including the *C. lindstromi* Zone in the Furongian (Stage 10). When *I. fluctivagus* is absent, *C. lindstromi* can be considered as an approximation of this systemic boundary.

Reassessing the GSSP of Green Point, Terfelt *et al.* (2012) observed that the specimens of *I. fluctivagus* illustrated by Cooper *et al.* (2001) would correspond to *I. preaengensis* Landing, which appears in the *Cordylodus intermedius* Zone (*Hirsutodontus simplex* Subzone) of late Cambrian age. Thereby, if the revision of Terfelt *et al.* (2012) were verified, the *C. lindstromi* Zone would be reestablished in the Tremadocian Stage.

Graptolites

Black shales from the upper Las Vicuñas Formation bear specimens of *Rhabdinopora* (Fig. 3), which are abundant in some levels. It is a monotonous graptolite fauna composed of siculae, proximal ends, and juvenile and mature rhabdosomes, usually incomplete and poorly preserved. Quadriradiate proximal development is observed in growth stages preserved in discoidal view. The rhabdosome outline form is variable, ranging from broad to narrow cone shape. The sicula is 1 mm in length. The stipes are sinous, spaced from 11 to 12.5 in 10 mm in the distal part of the rhabdosomes, but in some specimens this number can be 13 to 13.5. In the proximal part of some rhabdosomes it is possible to measure 9 stipes in 10 mm, but this spacing tends to be variable. Thecae, rarely preserved, are spaced in number of approximately 14 in 10 mm. Dissepiments are thin, normal to inclined to the stipes, and irregularly spaced throughout the mesh, counting more than 17 in 10 mm, in some specimens. This material resembles *R. flabelliformis parabola* in the presence of an irregular meshwork, with sinuous stipes. However, the stipes are closer spaced than in this subspecies (8-11 stipes in 10 mm), a character that does not allow safe taxonomic identification.

The graptolite material studied in the upper part of the Las Vicuñas Formation can tentatively be referred to the *Rhabdinopora flabelliformis parabola* Zone, the second graptolite zone of the Tremadocian Stage (Cooper *et al.*, 1998), until new information about this fauna is obtained.

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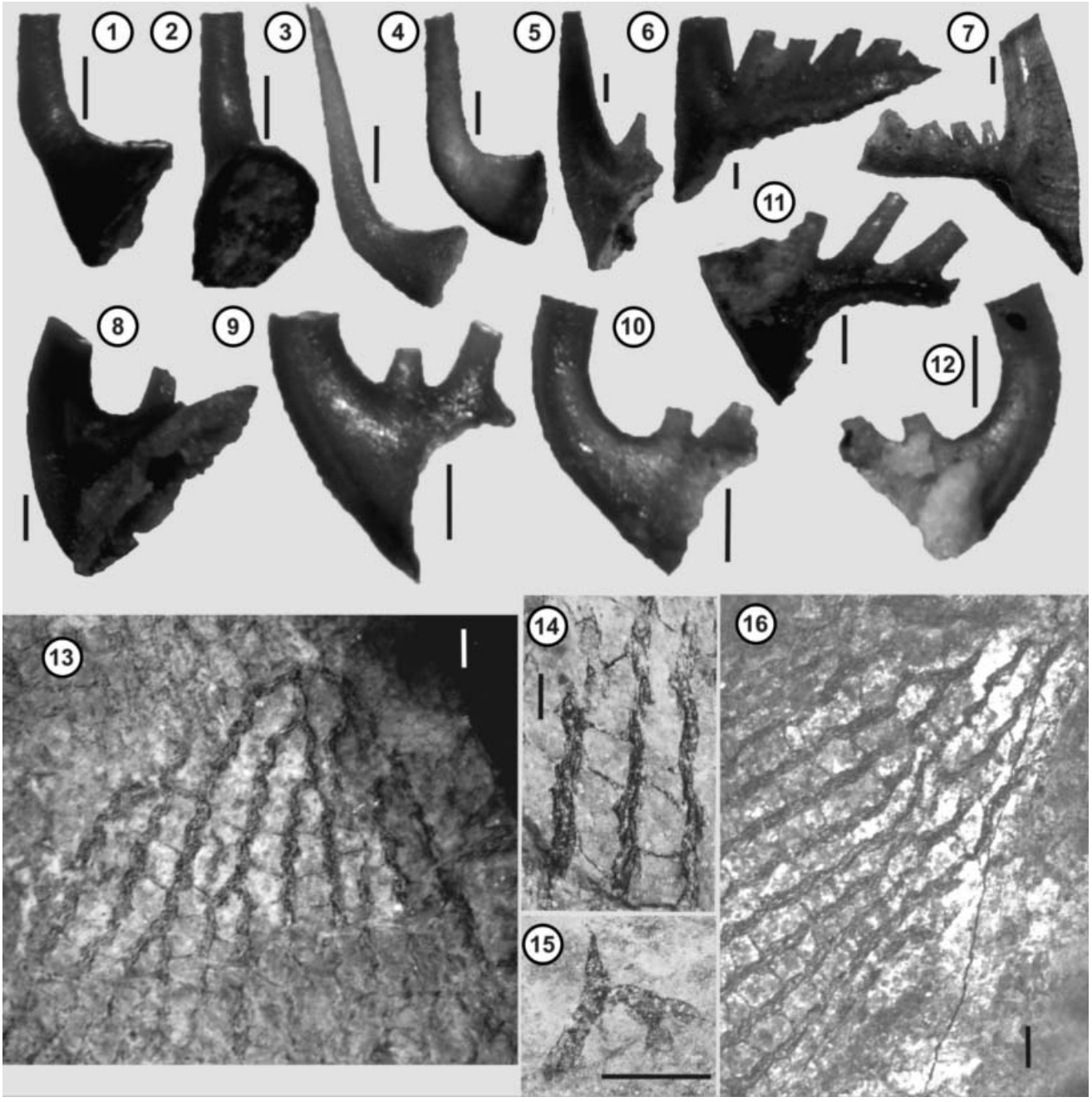

Figure 3. Upper Cambrian/Lower Ordovician conodonts (*Cordylodus lindstromi* Zone) and Lower Ordovician graptolites (*Rhabdinopora flabelliformis parabola* Zone) from Lari Creek, Puna Occidental, Salta Province, Argentina. **1-4**, *Teridontus nakamurai* (Nogami), **1**, Sb element, **2-3**, Sd element (CORD-MP 28403/1-24), **4**, Sc-Sb? element (CORD-MP 28048/1). **5-7**, *Cordylodus lindstromi* Druce and Jones, M elements, 5-7, (CORD-MP 28406/1-3). **8**, *Cordylodus deflexus* Bagnoli, Barnes and Stevens, compressed element S (CORD-MP 28405/1). **9-12**, *Cordylodus proavus* Müller, **9,11**, (CORD-MP 28401/1-13), **12**, (CORD-MP 28407/1). Scale bar: 0.1 mm. **13-16**, *Rhabdinopora flabelliformis* cf. f. *parabola*, **13**, Proximal part of mature colony with parabolic form (CORD-PZ 33057), **14**, detail of meshwork showing dissepiments and stipe dendroid structure (CORD-PZ 33055-b 1), **15**, proximal end (CORD-PZ 33055-b 2), **16**, mature rhabdosome (CORD-PZ 33061-b). Scale bar: 1 mm.

REFERENCES

Aceñolaza, F.G., Benedetto, J.L., Koukharsky, M., Salfity, J.A. and Viera, O. 1972a. Presencia de sedimentitas devónicas y neopaleozoicas en la Puna de Atacama, provincia de Salta, Argentina. *Asociación Geológica Argentina* 27 (3): 345-346. Notas breves.

Aceñolaza, F.G., Benedetto, J.L. and Salfity, J.A. 1972b. El Neopaleozoico de la Puna Argentina: Su fauna y relación con áreas vecinas. *Academia Brasileira de Ciencias, Anales* 44 (Suplemento): 5-20.

Albanesi, G.L., Esteban, S.B. and Barnes, C.R. 1999. Conodontes del intervalo del límite Cámbrico-Ordovícico en la Formación Volcancito, Sistema de Famatina, Argentina. *Temas Geológico-Mineros* ITGE 26: 521-526

Albanesi, G.L., Esteban, S.B., Ortega, G. Hünicken, M.A. and Barnes, C.R. 2005. Bioestratigrafía y ambientes sedimentarios de las Formaciones Volcancito y Bordo Atrasado (Cámbrico Superior-Ordovícico Inferior), Sistema de Famatina, provincia de La Rioja. *Asociación Geológica Argentina, Serie D: Publicación Especial* 8: 41-64.

Albanesi, G.L., Ortega, G., Zeballo, F.J. and Pacheco, F.E. 2010. The Cambrian-Ordovician boundary in South America: High resolution biostratigraphy, global correlation and paleoenvironments. *3th International Palaeontological Congress* (London): 67.

Barnes, C.R. 1988. The proposed Cambrian-Ordovician global boundary stratotype and point (GSSP) in Western Newfoundland, Canada. *Geological Magazine* 125 (4): 381-414.

Benedetto, J.L. and Sánchez, T.M. 1990. Fauna y edad del estratotipo de la Formación Salar del Rincón (Eopaleozoico, Puna, Argentina). *Ameghiniana* 27 (3-4): 317-326.

Carrera, M.G. 1998. First Ordovician sponge from the Puna región, Northwestern Argentina. *Ameghiniana* 35 (2): 205-210.

Cooper, R.A., Nowlan, G.S. and Williams, S.H. 2001. Global stratotype section and point for the base of the Ordovician System. *Episodes* 24 (1): 19-28.

Donato, E.O. and Vergani, G. 1985. Geología del Devónico y Neopaleozoico de la zona del cerro Rincón, provincia de Salta, Argentina. *IV Congreso Geológico Chileno*, Actas I: 268-283.

Galli, C.I., Moya M.C. and Arnosio, M. 2010. Estudios sedimentológicos en los depósitos carboníferos y pérmicos del borde occidental de la Puna. *Revista de la Asociación Geológica Argentina* 66(1): 119-132.

Isaacson, P.E., Antelo, B. and Boucot, A.J. 1976. Implications of a Llandovery (Early Silurian) brachiopod fauna from Salta Province, Argentina. *Journal of Paleontology* 50 (6): 1103-1112.

Koukharsky, M.M.L. 1988. El volcanismo ácido ordovícico y las rocas graníticas de la Puna occidental entre las latitudes 24º y 24º20´S. *Revista de la Asociación Geológica Argentina* 43: 253-256.

Koukharsky, M., Torres Claro, R., Etcheverría, M., Vaccari, N.E. and Waisfeld, B.G. 1996. Episodios volcánicos del Tremadociano y del Arenigiano en Vega Pinato, Puna salteña, Argentina. *XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos,* Actas V: 535-542.

Miller, J.F. 1988. Conodonts as biostratigraphic tools for redefinition and correlation of the Cambrian-Ordovician boundary. *Geological Magazine* 125: 349-362.

Moya, M.C., Malanca, S., Hongn, F.D. and Bahlburg, H. 1993. El Tremadoc temprano en la Puna Occidental Argentina. *XII Congreso Geológico Argentino y II Congreso de Exploración de Hidrocarburos,* Actas II: 20-30.

Nicoll, R.S., Miller, J.F., Nowlan, G.S., Repetski, J.E. and Ethington, R.L. 1999. *Iapetonudus* (n. gen.) and *Iapetognathus* Landing, unusual Earliest Ordovician multielement conodont taxa and their utility for biostratigraphy. *Brigham Young University Geology Studies* 44: 27-101.

Pacheco, F.E. 2009. *[Bioestratigrafía de conodontes y paleoambientes de la Formación Cardonal en la Sierra de Cajas, Cordillera Oriental, noroeste de Argentina.* Universidad Nacional de Córdoba. Facultad de Ciencias Exactas Físicas y Naturales, Córdoba. Tesis de Licenciatura, 116 pp. Inédito.].

Rao, R.I. 1999. Los conodontes cambro-ordovícicos de la sierra de Cajas y del Espinazo del Diablo, Cordillera Oriental, República Argentina. *Revista Española de Micropaleontología* 31: 5-20.

Rao, R.I., Moya, M.C. and Hünicken, M.A. 2000. Conodontes en la Formación Las Vicuñas (Tremadoc temprano), Puna occidental argentina. *Ameghiniana* 37 (4) Suplemento:13R.

Terfelt, F, Bagnoli, G. and Stouge, S. 2012. Re-evaluation of the conodont *Iapetognathus* and implications for the base of the Ordovician System GSSP. *Lethaia* 45 (2): 227-237.

Toro, B.A., Vaccari, N.E., Vento, B.A. and Balseiro, D. 2011. Implicaciones bioestratigráficas del estudio de las subespecies de graptolitos *Rhabdinopora flabelliformis* (Tremadociano) de la Cuenca Andina Central de Argentina y Bolivia. *Ameghiniana* 48 (4) Suplemento: R26.

Tortello, M.F., Rábano, I., Rao, R. and Aceñolaza, F.G. 1999. Los trilobites de la transición Cámbrico-Ordovícico en la quebrada Amarilla (Sierra de Cajas, Jujuy, Argentina). *Boletín Geológico y Minero* 110 (5): 555-572.

Vaccari, N.E., Toro, B.A., de la Puente, S.G. and Rubinstein, C.V. 2010. Nuevos aportes al conocimiento del Paleozoico inferior del área de Salar del Rincón, Puna occidental, Argentina. *X Congreso Argentino de Paleontología y Bioestratigrafía. VII Congreso Latinoamericano de Paleontología* (La Plata) Resúmenes: 56.

Zeballo, F.J., Albanesi, G.L. and Ortega, G. 2011. Biostratigraphy and paleoenvironments of the Santa Rosita Formation (Late Furongian-Tremadocian), Cordillera Oriental of Jujuy, Argentina. In Gutiérrez- Marco, J.C, Rábano, I. and García-Bellido, D. (Eds.), Ordovician of the World. *Cuadernos del Museo Geominero* 14: 625-632.